

Refraction of Light at a Plane Surface

Object:

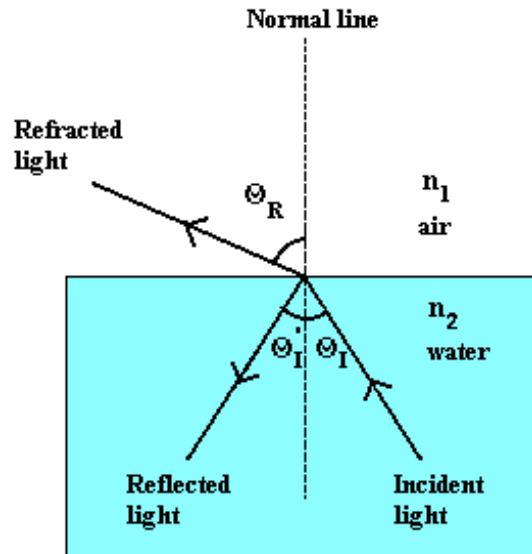
To study the refraction of light from water into air, at a plane surface.

Apparatus:

Refraction tank, 6.3 V power supply.

Theory:

The travel of light waves can often be approximate by straight lines (rays). The study of the properties of light with this approximation is called *geometric optics*. The figure below shows an example of light waves traveling in approximately straight lines. A thin beam of light, angled upwards from the lower right and traveling through water, encounters a flat surface (plane) of intersection between water and air. Part of the light is **reflected** by the surface, forming a beam directed downward toward the left. This reflected beam travels as if it bounced from the surface. The other portion of light travels through the surface and into the air, forming a beam directed upward and to the left. The travel of light through a surface (or interface) that separates two different materials is called **refraction**. The direction of the beam is “bent” at the surface as it travels from the water to the air, and is said to be *refracted*. Note that the bending occurs only at the surface.



The beams of light in the figure are represent by an *incident ray*, a *reflected ray*, and a *refracted ray*. Each ray is oriented with respect to a line, called the *normal*, that is perpendicular to the surface at the point of refraction and reflection. The *angle of incidence* is θ_I , the angle of reflection is θ_I' , and the angle of refraction is θ_R , all measured *relative to the normal* as shown.

The following laws apply to light beams reflecting and refracting at plane surfaces:

Law of Reflection:

$$\theta_i = \theta_r \quad (\text{reflection})$$

The angle of reflection is equal to the angle of incidence.

Law of Refraction:

$$n_2 \sin \theta_2 = n_1 \sin \theta_1 \quad (\text{refraction})$$

This equation is called Snell's law. It relates the angle of incidence to the angle of refraction via the use of two dimensionless numbers (n_1 and n_2) called the **index of refraction** for material one and two respectively. The index of refraction for air is approximately 1. The index of refraction for water will be measured in this experiment.

The Speed of Light Traveling in a Transparent Material:

By using Huygens' principle (Serway, section 35.6) one can show that the speed of a beam of light traveling in a transparent material is given by:

$$v = \frac{c}{n}$$

where c is the speed of light in vacuum (approximately 3.0×10^8 m/sec) and n is the index of refraction for the material.

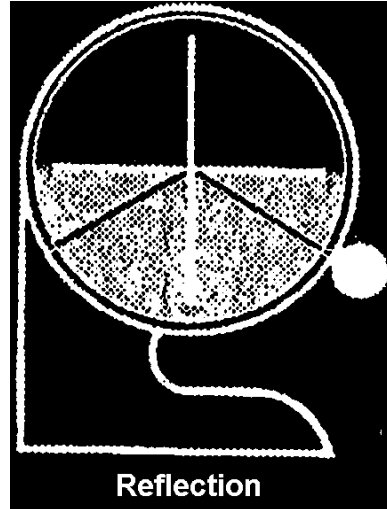
Procedure:

Adjusting the light source:

1. Position the light source at a preselected spot on the rim of the water bath and secure it in place using the fixing screw located on the back side of the bath.
2. Connect the light source cord to a dry cell or equivalent power supply (4-6V).
3. Light passing from the slit will fall upon the scale. Turn the slit plate until the light beam passes through the center of the bath.
4. Loosen the fixing screw and rotate the back cover of the light source either clockwise or counterclockwise until the sharpest image is formed (avoid using excessive force during this adjustment).

Experiment 1: Reflection of light

1. Place the circular water bath on a flat, level surface and fill it with water to the mid-line (90-90 line). This will require approximately 1 liter of water.
2. Position the light source to provide an angle of incidence of 50 degrees through the water. Measure the angle of reflection at 10 degree increments. Record the angle of reflection in the table below.

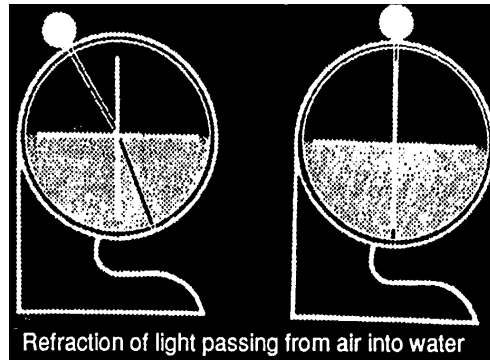


Data Table 1

Angle of incidence	50	60	70	80
Angle of reflection				
Percent difference				

Experiment 2: Refraction of light passing from air through water

1. Place the circular water bath on a flat, level surface and fill it with water to the mid-line (90-90 line). This will require approximately 1 liter of water.
2. Slowly move the light source from its top position (zero on the scale) downward while at the same time observing the path of the refracted light. Record the angle of the refraction on the table below.



Data Table 2

Angle of incidence (θ_I)	0	10	20	30	40	50	60	70	80
$\sin(\theta_I)$									
Angle of refraction (θ_R)									
$\sin(\theta_R)$									
Index of refraction for water									

Analyzing the data:

1. Find the average value of the index of refraction for water from the second experiment (from air through water).

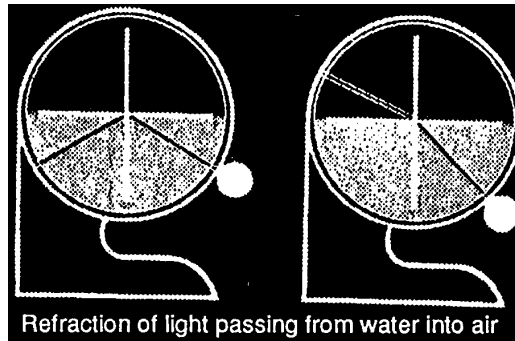
$$n_{w1} = \underline{\hspace{2cm}}$$

2. Compare the value of n_{w1} and the actual value of the index of refraction of water ($n_w = 1.333$).

$$\text{Percent Error} = \underline{\hspace{2cm}} \%$$

Experiment 3: Refraction of light passing from water through air

Fill the water bath as in the previous experiment, but this time very slowly move the light source up starting at the bottom position.



Data Table 3

Angle of incidence (θ_I)	0	10	20	30	40
$\sin(\theta_I)$					
Angle of refraction (θ_R)					
$\sin(\theta_R)$					
Index of refraction for water					

Analyzing the data:

1. Find the average value of the index of refraction for water from the third experiment (from water through air).

$$n_{w2} = \underline{\hspace{2cm}}$$

2. Compare the value of n_{w2} and the actual value of the index of refraction of water ($n_w = 1.333$).

$$\text{Percent Error} = \underline{\hspace{2cm}} \%$$

Experiment 4: Refraction of 90 degrees

1. Use Snell's law (with the average value of n_{w1} and n_{w2}), to calculate the angle of incidence (θ_c) from water into air which produces an angle of refraction equal to 90 degrees.

$$\theta_c = \underline{\hspace{2cm}} \text{ degrees}$$

2. Position the light source at the angle of incidence calculated in #1 above. Measure the angle of refraction.

$$\text{Measured refraction} = \underline{\hspace{2cm}} \text{ degrees}$$

$$\text{Percent difference} = \underline{\hspace{2cm}} \%$$

Questions:

1. Does the data from experiment 1 agree with the law of reflection? Why or why not?
2. Does the data from experiments 2 and 3 agree with the law of refraction? Why or why not?
3. Using the average value of n_{w1} and n_{w2} , find the speed of light in water. (the speed of light in the air $\approx 3 \times 10^8 \text{ m/s}$)

$$\text{Speed of light in water} = \underline{\hspace{2cm}} \text{ m/s}$$

